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Nutrient Uptake by Ryegrass Cultivars and Crabgrass from a Highly Phosphorus-Enriched Soil

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ABSTRACT

Long-term poultry litter application to crop and pasture lands may result in the buildup of nutrients, particularly phosphorus (P) in the soil. Poultry producers use poultry litter in place of chemical fertilizers to grow crops or forages for grazing and hay production. Cool-season annual ryegrass (*Lolium multiflorum*) and warm-season crabgrass (*Digitaria ciliaris*) are annual forages commonly grown in the southeastern region of USA. The combination of two forages gives year-round pasture for a forage-livestock system. A study was initiated to evaluate the P uptake efficiency of five ryegrass cultivars (Marshall, Rio, Jackson, TAM 90, and Gulf) grown during the winter and spring followed by the annual crabgrass

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variety Red River during summer. The experiment was conducted during the 2000 and 2001 growing seasons in Mize Mississippi on a highly P enriched Ruston silt loam soil. The ryegrass was grazed during winter then harvested once in early June. Cultivar Rio produced the greatest dry matter (DM) in both growing seasons. In 2001, due to optimum soil moisture conditions, cultivars Gulf and TAM 90 produced more DM than 2000, an extremely dry year. In 2001 crabgrass planted after TAM 90 produced significantly greater DM ($7565\,kg\,ha^{-1}$) than crabgrass following the other ryegrass cultivars. Cultivar Marshall was the most effective in removing P from soil in 2000 ($7.38\,kg\,ha^{-1}$), while Rio was superior in 2001 ($8.73\,kg\,ha^{-1}$). In general, crabgrass was more effective in P removal than ryegrass cultivars tested. Therefore, the combination of ryegrass followed by crabgrass may provide an effective forage-livestock management system in the southeastern states.

INTRODUCTION

Annual ryegrass (*Lolium multiflorum*) is an annual cool-season high quality forage, which is used throughout the southeastern USA for livestock grazing and hay production. September or early October is generally the best time to plant on a prepared seedbed or to over seed the dormant perennial warm season grasses.[1] While not tolerant to freezing temperatures and summer drought, ryegrass cultivars show a high degree of tolerance to climatic variations in temperate climates. In the southern states of USA, Italian ryegrass is often grown on acidic soils that have high concentration of soluble aluminum (Al).[2] However, Rengel and Robinson[3] reported that an increase in Al concentration increased the $K/(Ca + Mg)$ ratio of the ryegrass shoots, which increased the potential for grass tetany.

Crabgrass (*Digitaria ciliaris*), a summer annual, while considered a weed in many farming situations is a very productive forage for grazing and hay production. The nutritive quality of crabgrass is superior to warm season perennial grasses.[1] The combination of winter annual forage followed by crabgrass offers an alternative year-round green pasture system in the southeastern region of USA. This system utilizes the resources of solar energy, moisture, soil fertility, labor, time, and space more completely than a single crop system. The use of crabgrass in a pasture system has many benefits including an excellent component in many warm season forage mixtures, a good soil conservation grass, and an excellent grass for use in pasture-animal waste systems.

The build up of nutrients particularly phosphorus (P) in the surface soil layer as a result of long-term litter application to crop and pasturelands has

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become an environmental concern. Many forage grasses such as tall fescue (*Festuca arundinacea*), Italian ryegrass and orchardgrass (*Dactylis glamerata* L.) have been used to remove nitrogen (N) and P from wastewater.[4,5] Efficient P removing forages can utilize P and prevent the build up of P in soil.[6] Mackay et al.[7] explained differences in the ability of plants to remove P from soil. These differences are due to greater internal or external efficiency of P use, or a combination of the two. The internal mechanisms enable plant to produce more dry matter (DM) from a given amount of P absorbed, while externally efficient mechanisms enable plants to yield more because of an increased ability to extract P from the soil. Therefore, it is desirable to identify and use forage grasses or a combination of different forages that can acquire and use applied P efficiently. Normally, livestock require very small amounts of P in the herbage. However, in many pastures, herbage P concentrations exceed livestock needs.[8,9]

Identification of forage cultivars and varieties with greater capacity for growth and nutrient uptake offer considerable promise for increasing the sustainability of pasture and livestock production. Therefore, the objective of this study was to examine the differences among five annual ryegrass cultivars for P uptake and effect on soil P from a highly P enriched soil. The farmer's management practice in the area was followed by allowing the ryegrass to be grazed during the winter until mid-April and then harvested only once in early June at full maturity. In order to make it a year-round system, annual warm-season crabgrass was included during summer after the ryegrass was harvested.

MATERIALS AND METHODS

The study was conducted in each of 2 years (2000 and 2001) on a Ruston soil (Fine-loamy, siliceous, thermic Typic Paleudults) in Mize, MS. Soil of the study area is highly enriched with P (Mehlich-3 soil *P* test $>700\,\mathrm{mg\,kg^{-1}}$) as a result of more than 30 years of broiler litter application, $\sim 6\,\mathrm{Mg\,ha^{-1}}$ on a yearly basis.

The following chemical analyses were performed on ryegrass and crabgrass dry herbages (65°C) and soil samples (air dried). The pH was measured in a 1 : 1 soil : water ratio using 10 g soil. Total N (TN) and total carbon (TC) were measured by dry combustion using CE Elantec (formerly known as Carlo Erba) CN analyzer. Soil samples were extracted with 0.01 M KCl (1 : 10 soil : KCl) using 2 g soil, and analyzed for nitrate (NO_3-N) and ammonium (NH_4-N) using a Dionex-500 Ion Chromatograph (IC).[10] Soil samples were extracted with Mehlich-3 soil extractant[11] (1 : 10 soil : extractant) using 2 g soil, shaken for 30 min, and filtered through 2V Whatman brand

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filter paper for the determination of P and metals using a Thermo Jarrell-Ash Inductively Coupled Plasma Spectrophotometer (ICP), Franklin Massachusetts. Soil samples were also extracted with deionized water for water extractable P (WP). Soil total P (TP) was determined by digesting 0.50 g of air-dried soil using Sulfuric Acid, Hydrogen Peroxide, and Hydrofluoric Acid,[12] followed by the determination of P using ICP. Approximately 0.8 g plant tissue was ashed in a muffle furnace (Thermolyne Corporation 30,400, Doubuque, Iowa) at 500°C for 4 h. The ash was dissolved first in 1.0 mL of 6 N HCl for 1 h, followed by 50 mL of a double acid solution of 0.025 N H_2SO_4 and 0.05 N HCl, and the mixture was allowed to stand for another hour prior to filtration.[13] The ashed samples were used for the following analyzes: TP, potassium (K), calcium (Ca), magnesium (Mg), copper (Cu), iron (Fe), manganese (Mn), and zinc (Zn) using ICP. The initial soil chemical properties for the 0–10 cm depth were as follow: pH 5.79, TC 16.55 g kg^{-1}, TN 1.63 g kg^{-1}, NO_3-N 0.210 g kg^{-1}, NH_4-N 0.004 g kg^{-1}, TP 1,313 mg kg^{-1}, WP 34.60 mg kg^{-1}, M3-P 779.35 mg kg^{-1}, Ca 1.232 g kg^{-1}, Mg 0.171 g kg^{-1}, K 0.467 g kg^{-1}, Cu 26.23 mg kg^{-1}, Fe 329.35 mg kg^{-1}, Mn 121.23 mg kg^{-1}, and Zn 37.35 mg kg^{-1}. Broiler litter was hand-applied at 8.96 Mg ha^{-1} yr^{-1} (as-is basis) in early April. Chemical analysis of the litter sample showed the following nutrient content: P 19.7 g kg^{-1}, N 33.4 g kg^{-1}, K 34.5 g kg^{-1}, Zn 595 mg kg^{-1}, and Cu 501 mg kg^{-1}. The experiment was initiated in October 1999, in 2 × 5 m plots in a randomized complete block design with four replications. Five cultivars of ryegrass were selected as followed: Marshall, Jackson, Rio, TAM 90, and Gulf. In the middle of January, when the plant height was about 25 cm, cattle were allowed to graze the ryegrass for ~3 months up to April. After the ryegrass was harvested once in early June, crabgrass (variety Red River) was sown at 3.36 kg ha^{-1} by uniformly broadcasting the seeds into the ryegrass residue. The experiment was repeated for the second growing season.

The data were analyzed using the GLM procedure in SAS.[14] Due to the significant ($P \leq 0.05$) interaction between dry herbage weight DM and year, the data were sorted, analyzed, and reported by year. Cultivar means DM yield and nutrient uptake were separated by LSD ($P \leq 0.05$).

RESULTS AND DISCUSSION

Dry Matter Yield

Ryegrass cultivar Rio produced the most DM followed by Marshall, Jackson, TAM 90, and Gulf in 2000. In 2001 Rio was also superior in DM yield followed by TAM 90, Jackson, Gulf, and Marshall (Table 1). Gulf and

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Table 1. Ryegrass cultivars DM, TN, TP, Ca, Mg, K, Na, Cu, Fe, Mn, and Zn for 2000 and 2001.

Ryegrass cultivar	DM (kg/ha)	TN (g/kg)	TP (g/kg)	Ca (g/kg)	Mg (g/kg)	K (g/kg)	Na (g/kg)	Cu (mg/kg)	Fe (mg/kg)	Mn (mg/kg)	Zn (mg/kg)
2000											
Rio	2,839	12.4	2.37	3.29	1.05	19.49	1.04	6.01	55.55	57.92	60.53
Marshall	2,764	15.1	2.65	3.73	1.25	22.29	1.19	6.51	62.34	54.31	67.71
Jackson	2,427	13.5	2.64	3.8	1.15	19.36	0.98	5.78	70.53	69.24	74.70
TAM 90	2,251	13.8	2.51	3.72	1.14	19.10	2.05	6.86	54.96	62.36	66.72
Gulf	1,993	12.8	2.22	3.32	0.99	17.25	1.67	5.60	70.79	49.66	62.48
LSD[a]	418	2.51	0.39	0.83	0.21	3.87	0.58	2.30	24.48	23.74	12.45
2001											
Rio	2,043	7.28	2.90	5.33	1.32	12.89	0.44	3.05	121.1	187.9	71.82
Marshall	1,994	7.20	2.72	5.20	1.40	11.41	0.33	2.43	131.5	201.8	59.96
Jackson	2,462	6.96	2.69	5.33	1.27	11.68	0.35	2.67	87.1	200.2	68.18
TAM 90	2,605	6.13	2.93	5.42	1.35	10.48	0.45	2.59	107.6	220.8	69.88
Gulf	2,448	6.70	2.70	4.44	1.116	11.04	0.44	2.65	106.0	183.0	63.05
LSD[a]	731	1.31	0.46	0.79	0.18	1.79	0.12	1.35	54.5	57.85	10.47

[a]The least significant differences (LSD, 0.05) compares each parameter (column) within each year.

TAM 90 produced greater DM yields in 2001 than 2000 (very dry year), which indicate that these cultivars were more sensitive to drought than the other cultivars. Due to the severe drought in the summer of 2000, crabgrass produced minimal dry herbage. However, the growth was excellent in 2001. There were no significant differences among the crabgrass yields produced from the same plots that the five ryegrass cultivars were planted in 2000. But in 2001, crabgrass that followed the ryegrass cultivar TAM 90 produced significantly greater DM yield than the crabgrass following other cultivars (Table 2). There were no differences among the DM yield of crabgrass planted after ryegrass cultivars Rio, Marshall, Gulf, and Jackson.

Herbage Nutrient Concentration

Total N concentration of all ryegrass cultivars and crabgrass were greater in 2000 than 2001. Cultivar Marshall herbage had the greatest TN content in 2000 while there were no significant differences among the ryegrass cultivars in 2001 (Tables 1 and 2). Phosphorus content of all ryegrass cultivars ranged from 2.22 to 2.93 $g\,kg^{-1}$ in both years. The weather conditions, particularly precipitation and soil moisture, impacted the herbage TN more than the P concentration for all cultivars. While TP concentration of ryegrass dry herbage were similar to those reported by Brink et al.,[15] the Cu and Zn concentration were greater than those reported by Brink et al.[15] The K concentration of dry herbage of ryegrass cultivars and crabgrass was much greater than Ca and Mg. The $K/(Ca + Mg)$ ratio, which is a forage quality parameter, were 4.5, 4.5, 3.9, 3.9, and 4.0 for Rio, Marshall, Jackson, TAM 90, and Gulf respectively, in 2000 (Table 1). These ratios were greater than 2.2, the point at which forage is considered tetany prone.[16] However, in 2001 an optimum year with regard to precipitation and soil moisture content compared to 2000, all the ryegrass cultivars had lower than 2.2 $K/(Ca + Mg)$ ratio. The $K/(Ca + Mg)$ ratio for crabgrass tissue content ranged from 4.5–8.0 in 2000 and 2001, which was much greater than 2.2 limit for grass tetany. No significant differences in ryegrass cultivar DM Fe and Mn content were observed in 2000 and 2001. The cultivar Rio DM Zn content was smallest in 2000 (dry year) while it was the greatest in 2001 (Table 1).

Phosphorus Uptake

Since the study was conducted on a highly P enriched soil, we were interested in quantifying the effectiveness of each ryegrass cultivar with crabgrass in P removal from soil. The P uptake was calculated as the product of DM yield and DM P concentration. The cultivar Marshall was the most

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Table 2. Dry matter, TN, TP, Ca, Mg, K, Na, Cu, Fe, Mn, and Zn content of crabgrass grown after different ryegrass cultivars for 2000 and 2001 growing seasons.

Crabgrass (ryegrass)	DM (kg/ha)	TN (g/kg)	TP (g/kg)	Ca (g/kg)	Mg (g/kg)	K (g/kg)	Na (g/kg)	Cu (mg/kg)	Fe (mg/kg)	Mn (mg/kg)	Zn (mg/kg)
2000											
Crabgrass (Rio)[a]	393	29.89	3.74	2.79	3.33	47.13	1.01	9.61	189.3	135.9	100.1
Crabgrass (Marshall)	394	32.25	4.01	2.63	3.28	48.94	1.08	10.36	131.9	171.8	134.7
Crabgrass (Jackson)	432	28.03	3.79	2.65	3.40	47.19	1.21	9.76	135.8	139.1	118.2
Crabgrass (TAM 90)	400	29.46	3.75	2.55	3.26	46.35	1.02	9.67	160.1	144.9	109.3
Crabgrass (Gulf)	430	28.03	3.76	2.60	3.21	45.54	1.02	10.51	143.3	162.9	106.9
LSD[b]	68.0	5.9	0.41	0.42	0.31	4.42	0.29	1.47	65.0	82.0	20.9
2001											
Crabgrass (Rio)	6,391	9.86	5.85	2.42	3.10	24.34	0.24	5.05	61.0	136.7	98.9
Crabgrass (Marshall)	6,407	9.83	5.77	2.49	3.04	25.81	0.22	4.55	63.4	178.6	104.7
Crabgrass (Jackson)	6,066	9.64	5.59	2.54	3.11	26.00	0.21	4.32	55.8	151.3	104.7
Crabgrass (TAM 90)	7,565	8.76	5.55	2.31	2.78	24.00	0.20	4.45	42.7	179.3	98.6
Crabgrass (Gulf)	6,748	9.36	5.16	2.44	2.83	23.89	0.22	3.78	70.4	150.8	89.9
LSD[b]	728	1.67	1.24	0.30	0.41	3.52	0.11	1.28	27.15	44.5	17.7

[a]Crabgrass grown after different ryegrass cultivar shown in parentheses.
[b]The least significant differences (LSD, 0.05) compares each parameter (column) within each year.

effective in removing P in 2000 (dry year), while Rio was most effective in 2001 (Fig. 1). This indicates that the ryegrass cultivar Rio is superior in removing P under optimum moisture condition. It is also puzzling why the cultivar Marshall did not produce a greater yield in 2001, when the growth conditions were better than 2000 in regard to precipitation and soil moisture availability. The cultivar Gulf was the least effective in P uptake in 2000 but similar to Jackson and Marshall in 2001. The P uptake by crabgrass in the year 2000 was completely impacted by the severe drought during the summer. No significant differences were observed in P uptake of crabgrass harvested after ryegrass cultivars TAM 90, Marshall, Jackson, and Rio in 2001 (Fig. 2). However, crabgrass harvested after ryegrass cultivar TAM 90 removed significantly more P than crabgrass harvested after cultivar Gulf.

Soil Nutrient Composition

Table 3a and 3b show the soil nutrient content after each ryegrass cultivar harvest in June 2000. The concentrations of nutrients were consistently greater in the 0–5 cm depth than 5–10 cm, due to the surface application of litter without any incorporation. There were no significant differences among pH, TC, TN, NO_3-N, NH_4-N, and M3-P of the soil samples collected (both depths) from the plots of different ryegrass cultivars. However, significant differences were

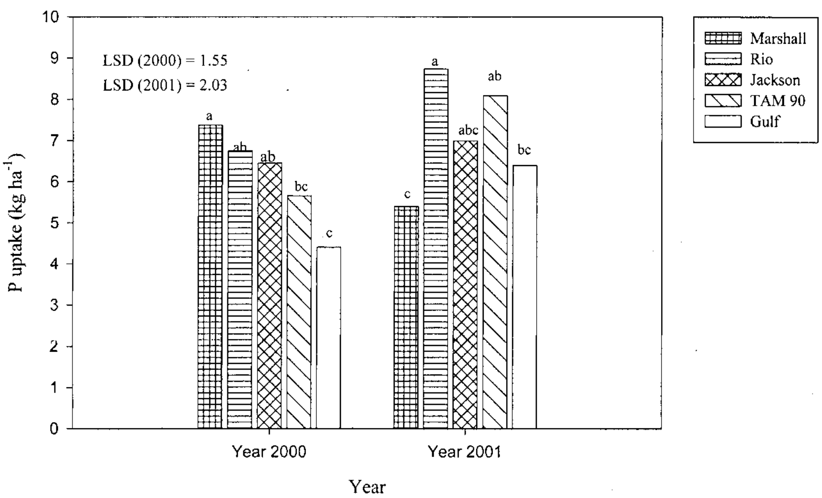

Figure 1. Phosphorus uptake by ryegrass cultivars during 2000 and 2001 growing seasons.

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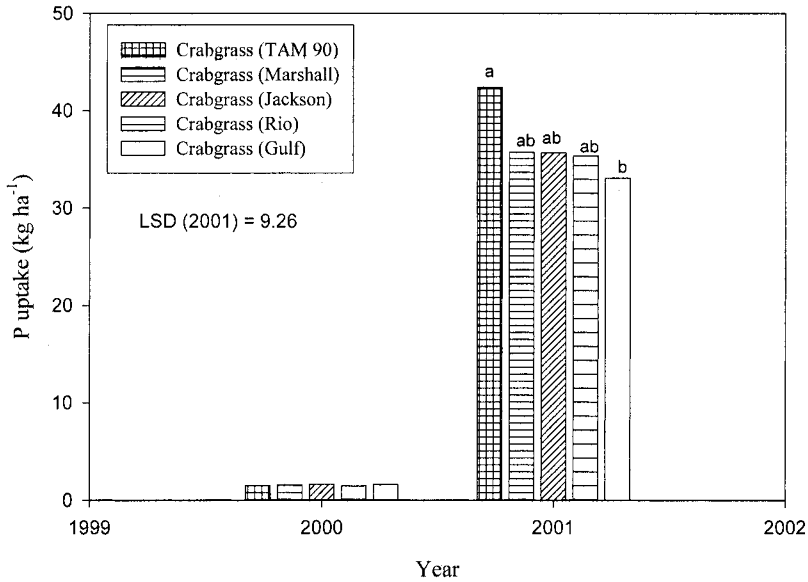

Figure 2. Phosphorus uptake by crabgrass grown after five ryegrass cultivars during 2000 and 2001 growing seasons.

observed in TP (0–5 cm), WP, Cu, and Zn for the depth 5–10 cm. Average soil pH increased slightly from 5.8 (background) to 5.9 at the end of first ryegrass harvest (2000) then decreased to 5.1 at the end of second harvest (2001). Normally, it is expected that soil pH increases in the long term upon broiler litter application. In 2001, at the end of second growing season, a noticeable decline in all soil P fractions (TP, WP, and M3-P) was observed compared to the background and 200 values for these fractions. This net reduction indicated that substantial P removal by all ryegrass cultivars and crabgrass had taken place (Tables 3a, 4a, and 4b). For instance, averaged across all cultivars and soil depth, the M3-P values were 779, 831, and 615 mg kg^{-1} for background, 2000, and 2001, respectively. The slight increase in 2000 was due to extremely summer drought, which impacted the crabgrass growth and the P uptake.

CONCLUSIONS

The use of cool-season ryegrass followed by the warm-season crabgrass presents an alternative year-round pasture to perennial bermudagrass over seeded with ryegrass during the winter. For many forage-livestock producers,

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Table 3a. Soil pH, TC, TN, nitrate nitrogen (NO_3-N), ammonium nitrogen (NH_4-N), TP, WP, and Mehlich 3 extractable phosphorus (M3-P) after ryegrass harvest in 2000.

Ryegrass cultivar	Soil depth (cm)	pH	TC (g/kg)	TN (g/kg)	NO_3-N (g/kg)	NH_4-N (g/kg)	TP (mg/kg)	WP (mg/kg)	M3-P (mg/kg)
Rio	0–5	6.2	19.9	2.01	0.17	0.03	1,568	52.53	857
	5–10	5.8	14.3	1.33	0.05	0.01	1,255	41.21	719
Gulf	0–5	6.2	17.7	1.86	0.12	0.02	1,608	61.12	919
	5–10	5.7	14.8	1.34	0.07	0.01	1,275	40.77	742
TAM 90	0–5	6.2	17.9	1.78	0.10	0.02	1,403	60.66	866
	5–10	5.7	14.3	1.30	0.04	0.01	1,117	35.80	731
Marshall	0–5	6.0	20.2	2.10	0.10	0.01	1,783	53.84	933
	5–10	5.7	18.2	1.81	0.08	0.01	1,538	50.42	893
Jackson	0–5	6.1	19.3	1.94	0.09	0.01	1,440	45.92	859
	5–10	5.7	15.4	1.48	0.04	0.01	1,230	41.33	787
LSD[a]	0–5	ns	ns	ns	ns	ns	377	ns	ns
	5–10	ns	ns	ns	ns	ns	ns	14.5	ns

[a]The least significant differences (LSD, 0.05) compares each parameter (column) within each cultivar and soil depth.

Table 3b. Soil concentration of Ca, Mg, K, Na, Cu, Fe, Mn, and Zn after ryegrass harvest in 2000.

Ryegrass cultivar	Soil depth (cm)	Ca (g/kg)	Mg (g/kg)	K (g/kg)	Na (g/kg)	Cu (mg/kg)	Fe (mg/kg)	Mn (mg/kg)	Zn (mg/kg)
Rio	0–5	1.37	0.20	0.61	0.21	33.9	397	131.1	43.0
	5–10	1.02	0.13	0.33	0.19	23.5	409	119.1	28.1
Gulf	0–5	1.37	0.21	0.60	0.22	32.8	400	130.1	41.0
	5–10	1.04	0.14	0.35	0.18	25.6	410	120.9	28.9
TAM 90	0–5	1.29	0.18	0.52	0.19	33.6	385	131.1	41.9
	5–10	0.98	0.11	0.30	0.17	26.5	406	124.5	30.2
Marshall	0–5	1.45	0.19	0.56	0.22	35.7	417	125.9	47.7
	5–10	1.34	0.14	0.34	0.19	32.1	433	120.4	42.5
Jackson	0–5	1.38	0.20	0.46	0.21	33.9	416	125.9	42.7
	5–10	1.12	0.13	0.31	0.20	29.8	439	122.2	34.3
LSD[a]	0–5	ns	ns	ns	ns	ns	ns	ns	ns
	5–10	ns	ns	ns	ns	7.5	ns	ns	12.7

[a]The least significant differences (LSD, 0.05) compares each parameter (column) within each cultivar and soil depth.

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Table 4a. Soil pH, TC, TN, nitrate nitrogen (NO_3-N), ammonium nitrogen (NH_4-N), TP, WP, and Mehlich 3 extractable phosphorus (M3-P) after ryegrass harvest in 2001.

Ryegrass cultivar	Soil depth (cm)	pH	TC (g/kg)	TN (g/kg)	NO_3-N (g/kg)	NH_4-N (g/kg)	TP (mg/kg)	WP (mg/kg)	M3-P (mg/kg)
Rio	0–5	5.1	17.7	1.65	0.05	0.07	1,194	39.15	623
	5–10	4.9	13.1	1.13	0.23	0.01	1,089	40.42	576
Gulf	0–5	5.2	19.4	1.90	0.13	0.02	1,262	37.79	630
	5–10	5.0	12.6	1.16	0.03	0.01	1,052	35.50	524
TAM 90	0–5	5.2	16.5	1.59	0.05	0.01	1,173	36.62	653
	5–10	5.0	11.9	1.05	0.02	0.01	967	34.45	511
Marshall	0–5	5.1	19.7	2.01	0.07	0.02	1,457	43.29	741
	5–10	4.9	15.5	1.46	0.02	0.01	1,315	45.40	699
Jackson	0–5	5.1	18.2	1.78	0.04	0.01	1,299	38.88	631
	5–10	5.1	13.6	1.24	0.03	0.01	1,083	35.55	560
LSD[a]	0–5	ns	ns	ns	0.07	ns	268	ns	ns
	5–10	ns	0.27	0.37	0.01	ns	314	10.28	183

[a]The least significant differences (LSD, 0.05) compares each parameter (column) within each cultivar and soil depth.

Table 4b. Soil concentration of Ca, Mg, K, Na, Cu, Fe, Mn, and Zn after ryegrass harvest in 2001.

Ryegrass cultivar	Soil depth (cm)	Ca (g/kg)	Mg (g/kg)	K (g/kg)	Na (g/kg)	Cu (mg/kg)	Fe (mg/kg)	Mn (mg/kg)	Zn (mg/kg)
Rio	0–5	1.12	0.11	0.36	0.10	24.0	113	95.6	29.6
	5–10	0.94	0.09	0.24	0.10	20.8	110	88.5	22.6
Gulf	0–5	1.17	0.11	0.39	0.09	24.6	112	92.5	31.9
	5–10	0.88	0.08	0.27	0.10	19.7	109	83.6	20.2
TAM 90	0–5	1.12	0.10	0.32	0.10	25.6	111	95.8	32.2
	5–10	0.82	0.07	0.21	0.09	21.1	107	89.4	21.6
Marshall	0–5	1.30	0.11	0.40	0.09	29.4	112	80.9	39.7
	5–10	1.15	0.10	0.30	0.10	26.3	113	76.0	30.9
Jackson	0–5	1.12	0.11	0.34	0.10	25.8	112	79.3	32.0
	5–10	0.95	0.09	0.23	0.11	22.4	110	78.2	24.7
LSD[a]	0–5	ns	ns	ns	ns	4.1	ns	16.1	9.1
	5–10	0.3	ns	ns	ns	5.9	4.9	ns	9.1

[a]The least significant differences (LSD, 0.05) compares each parameter (column) within each cultivar and soil depth.

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in the southeast USA, where broiler litter is the source of fertilizer, forages with high capacity of removing residual nutrient particularly P, from soil is desirable in order to reduce the potential nutrient loss to the environment by runoff. These results indicated that ryegrass cultivars Rio or Marshall followed by crabgrass variety Red River produced the most DM yield and removed significant quantity of P, Cu, Fe, Mn, and Zn from soil. However, other ryegrass cultivars such as Jackson and TAM 90 also performed well under optimum moisture conditions. Separately, crabgrass is a more effective P remover than the ryegrass cultivars tested. The results of this study also showed that in 2000 ryegrass and crabgrass dry matter contained much greater $K/(Ca + Mg)$ ratio than 2.2, a ratio that may cause grass tetany in animals. Therefore, does high broiler litter applications and high nutrient uptake in forages increases the probability of grass tetany? This may be of great concern for grazing animals on poultry litter fertilized pastures or utilization of hay from these fields.

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